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SEMI-ANNUAL REPORT

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BULK FORMATION OF METALLIC GLASSES AND AMORPHOUS SILICON FROM THE MELT

Prepared For

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The objectives of our research are:

(1) to find new procedures and compositions for producing metallic glasses in bulk at slow cooling rates;

(2) to attempt to form the amorphous phase of the tetrahedrally coordinated elements (Si or Ge) by undercooling the melt; and

(3) to examine the crystal nucleation behavior of pure liquids and glass formers experimentally and theoretically.

The following progress can be reported:

1. Bulk Formation of Metallic Glasses (Work by H.W. Kui)

We have continued our experiments on the bulk formation of $Pd_{40}Ni_{40}P_{20}$ glass. Drehman et al (1) had succeeded in forming a sphere of about 1 cm diameter of this material by surface cleaning and repeated melting and cooling in an evacuated tube, with the sample supported on a fused silica substrate.

Kui has succeeded in forming similar amounts of glass in a B_2O_3 glassy flux. In contrast with the earlier results, no evidence was found of any surface crystallization. The reproducibility of the glass formation was also improved.

2. Bulk Formation of Amorphous Ge or Si (Work by G. Devaud)

We have started exploratory undercooling experiments on germanium, using the 10' drop tube used by Drehman for his work on Pd-Si glasses (2). The vacuum of the tube has been improved, as has the droplet injection technique. We expect that, if an undercooling of about 250K can be achieved, formation of the amorphous phase may be kinetically favored.

3. Crystal Nucleation in Pure Metals (Work by H.W. Kui)

We have succeeded in performing high precision dilatometric measurements on dispersions of Ga droplets in an organic fluid as a function of undercooling. We have indications that, under certain conditions, the liquid Ga is put increasingly under hydrostatic tension as the undercooling increases, presumably due to the differential expansion between the Ga droplets and their oxide coating. These conclusions are only preliminary, however, and need to be confirmed by further measurements.

4. Transient Crystal Nucleation in Glass Forming Melts (Work by K.F. Kelton and A.L. Greer)

We have continued our theoretical study of transient crystal nucleation by extending the earlier work, under isothermal conditions (3), to continuous quenching, which corresponds more realistically to the experimental conditions. It was applied to a number of glass formers: for $LiO_2 \cdot 2SiO_2$, the critical cooling rate for glass formation, $\dot{T}_c$, was found to be 3.8 K/sec for both the transient and steady state nucleation; for $(Au_{100-y}Cu_y)_{77}Si_9Ge_{14}$, $\dot{T}_c$ for transient nucleation was 4.5×10^3 K/sec, whereas steady state nucleation required 1.3×10^4 K/sec; for Au_4Si, $\dot{T}_c$ for transient nucleation was 1.4×10^5 K/sec, compared to 2.5×10^7 K/sec for steady state. Note that for the last material, transient nucleation must be invoked to explain glass formation by disk quenching (typically at 10^6 K/sec).

References

(1) A.J. Drehman, A.L. Greer and D. Turnbull, Appl. Phys. Lett., 41, 716 (1982).

(2) A.J. Drehman and D. Turnbull, Scripta Met., 15, 543 (1981).

(3) K.F. Kelton, A.L. Greer and C.V. Thompson, J. Chem. Phys., 79, 6261 (1983).

Publications (Copies of these papers are appended.)

C.V. Thompson and F. Spaepen, "Homogeneous Crystal Nucleation in Binary Metallic Melts", Acta Met., 31, 2021 (1983).

C.V. Thompson, A.L. Greer and F. Spaepen, "Crystal Nucleation in Amorphous $(Au_{100-y}Cu_y)_{77}Si_9Ge_{14}$ Alloys", Acta Met., 31, 1883 (1983).

K.F. Kelton, A.L. Greer and C.V. Thompson, "Transient Nucleation in Condensed Systems", J. Chem. Phys., 79, 6261 (1983).